Spring 5-2-2013

Moving Toward Sustainable Production of Charcoal in Sub-Saharan Africa: A Teaching Case Study

Justin Taylor Roop
jroop2@utk.edu

Moving Toward Sustainable Production of Charcoal in Sub-Saharan Africa: A Teaching Case Study

Justin T. Roop
University of Tennessee
Chemistry Department
Knoxville, TN 37996

Abstract

In the developing world, wood fuels play a major role in supplying energy needs. In sub-Saharan Africa, much of this wood fuel is in the form of charcoal used for cooking. As much as 90% of the cooking performed in these countries use charcoal as the energy source. With this massive quantity being produced and sold, the charcoal sector presents a major area in which sustainable development can be implemented with a large positive impact. At present, deforestation, pollution, and inequitable distribution of profits threaten the long-term viability of this industry. This teaching case study presents the background of the charcoal sector, the sustainability challenges being faced, and proposes courses of action to address these challenges. Also included are teaching notes and discussion questions with answers that make this teaching case study suitable for application in a high school senior classroom or a college undergraduate course focused on sustainability or a related topic.

Introduction

As is the case in many developing countries, wood fuels play a major role in supplying the energy needs of the people in sub-Saharan Africa. The need for wood fuels arises from the low electrification rate in these developing countries. For example, in Malawi only 30% of urban households are on the electric grid. Of those 30% that have electricity, only 38% use electricity for cooking.[1] In Tanzania energy from wood fuels account for 90% of the country's energy consumption.[2] Of these wood fuels, charcoal is a prevalent choice, especially in urban settings were ease of transport and low storage space are of high importance. By definition, charcoal is the amorphous, porous form of carbon that results from the slow pyrolysis of wood fuel. During the production process, the volatile and liquid matter is driven off leaving behind an energy-rich form of carbon that is lightweight making it easy to transport and store. A simplified representation of the pyrolysis process can be seen in Figure 2.

Figure 1: The charcoal value chain showing the five stages from harvesting of the wood fuel to final usage by the consumer[4]

The demand for charcoal is greater today than ever before, and it is only expected to increase over the coming years as population increases lead to an even greater need for energy sources.[3] This ever-growing demand for charcoal contributes to many sustainability challenges that must be addressed if these energy needs are going to continue to be met.

The value chain for the charcoal sector is shown in Figure 1. In each of these five areas, there exists opportunity to move toward more sustainable practices that would ensure the availability of charcoal for the coming generations. Without intervention, the business-as-usual model for charcoal will not only rob future generations of their ability to supply their energy needs, but will rob Africa of its native forests and biodiversity through deforestation and forest degradation. It is the goal of this teaching case study to chart a plausible course by which to move the charcoal sector of sub-Saharan Africa toward sustainability.

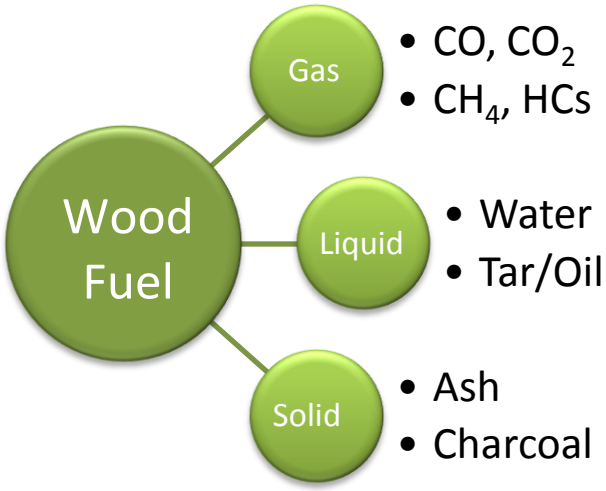

Figure 2: Simplified representation of the slow pyrolysis process.

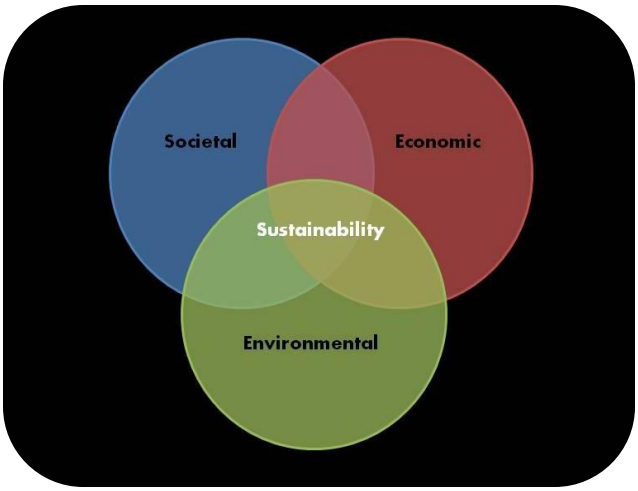

Figure 3: Venn diagram displaying the three areas that must be considered when discussing sustainability

Sustainability Challenges

As previously stated, each link of the charcoal

value chain has need of improvement toward more sustainable practices. However, it is important to note, changes that positively affect environmental considerations of this study may very well have negative impacts on either economic aspects, societal aspects, or both. The difficulty in a sustainability problem such as this lies in addressing every challenge in a way that helps achieve a balance between the three. In this case study, each of the three areas of sustainability, environmental, economic, and societal, will be addressed separately with general conclusions drawn at the closing.

Economic Challenges for Sustainability

The charcoal sector is a considerable contributor to the economies of countries in sub-Saharan Africa. For example, the annual revenue of the charcoal sector in Tanzania is $650M. There are hundreds of thousands of workers that are employed as a result of the charcoal industry with these jobs being found in both rural and urban areas.[2] From these numbers, it would be thought that the industry is economically sustainable, but that is not the case. Despite the magnitude of this industry, there exist barriers to sustainability that threaten its viability going forward.

Economic sustainability barriers stem from three primary sources. The first source of economic sustainability challenge is the fact that there is a concentration of power within the charcoal sector in the hands of a few people.[3] These power players are mainly found in the transporting and wholesaling of charcoal where the volume of charcoal in which they deal is quite large. By controlling the middle of the supply chain they are then able to dictate many aspects of pricing across the value chain which leads to lopsided income levels from stage-to-stage of the charcoal industry. By some estimates, transporters/wholesalers in Mozambique make about 71% of the total profit with producers making 21% and retailers making only the remaining 8% of the profit from the charcoal value chain.[4] With this imbalance of income, producers and retailers are placed at a distinct disadvantage. Sustainability overall is also adversely affected as producers with disproportionately low income levels are held to a lower class in society and are also much less likely to invest in more efficient kiln technologies that could help with environmental sustainability.

A second economic challenge to sustainability is the rampant evasion of licensing fees and taxes on charcoal that is being produced and sold. It is estimated that governments in Tanzania, considering both local and national levels, lose $100M every year as a result of the lack of enforcement of taxes and licensing fees.[2] This is also a byproduct of the concentration of power as the few people in control of the charcoal industry are also heavily involved in political corruption. That is how they are permitted to avoid such taxes and fees. Correction of this problem through proper enforcement of the tax code and

complete collection of licensing fees would provide a large stream of revenue from which governments could fund suppression of other illegal and nonsustainable practices across the charcoal value chain.

The third economic challenge facing sustainability of charcoal production in sub-Saharan Africa is improper value being placed on charcoal. In addition to the top-heaving income distribution described above, and as a direct result of the avoided taxes and fees just discussed, charcoal is being sold at the retail level at a value that does not properly reflect its true value.[1] One other contributing factor to this is illegal deforestation practices. These will be discussed further in the environmental challenges section of this case study, but it is important to note that illegally harvested wood has no value placed on it since no price was paid to obtain it. With no value placed on the crude starting material, the overall value of charcoal is skewed from the beginning. Proper valuation of the materials and processes would provide more income for all of the players involved and further facilitate appropriate distribution of profits.

Environmental Challenges for Sustainability

The environmental challenges associated with the charcoal sector lie predominantly in the first two links of the value chain, forest management and production. With regard to forest management, deforestation as a result of improper oversight of wood fuel collection practices has had very detrimental effects. As a result of these practices, Africa has lost over 1/3 of its native forests.[3] In almost every case, there exists no current reforestation plans to try and reverse the damage that has been done. Once the wood has been harvested, another environmental concern arises in the form of pollution produced at the site of production. This pollution is a threat not only to the environment as a whole, through greenhouse gas emissions, but it also poses a health risk to those in close proximity to the kiln during firing. These environmental concerns must be properly addressed if the production of charcoal is going to move toward sustainability.

Deforestation and forest degradation have long been a problem in Africa. Africa's rate of deforestation is more than twice that of the world average. That equates to the addition of more than 4 million hectares (nearly 10 million acres) of deforested land every year.[5] Charcoal production and the use of wood fuels in general are certainly contributors to such high numbers of trees felled, but it is the illegal harvesting of the trees without any reforestation or forest management practices that is causing the loss of those forests. If properly managed, wood can be a sustainable energy source for Africa. However, a large percentage of the wood being harvested for charcoal production in sub-Saharan Africa is being done illegally.[3] The economic implications of this have been discussed above, but the environmental repercussions are even greater. The danger goes beyond just losing the ability to produce charcoal and threatens biodiversity and the balance of the African ecosystem as a whole.

The link between emissions of greenhouse gasses and global climate change necessitate that emissions from kilns used to produce charcoal must be addressed if the charcoal sector of sub-Saharan Africa is to be considered sustainable. Table 1 shows data collected by Pennise et al. from a study where they looked at greenhouse gas emissions associated with charcoal production in Brazil and Kenya.[6] In the first two cases (KEM 1- 2), the kilns were constructed and operated by members of University of Nairobi's grounds staff using traditional methods. KEM 3-5 were constructed and operated by migrant charcoal makers. A selection of different trees reflective of wood fuel used normally in Kenya was used including Cronton megalopis (KEM 1), eucalyptus (KEM 2), and black wattle (KEM 3-5). While % yield of charcoal can be seen to increase with different wood sources, emission factors remain quite high. In each case there was more CO_2 produced than charcoal. Such studies show the dire situation as it stands presently.

Kiln Type	% Charcoal Yield[1]	Emission Factors, g of Pollutant per kg of Charcoal Produced						
		CO_2	CO	CH_4	TNMHC[2]	N_2O	NO_x	TSP[3]
Kenyan Earth Mound (KEM) 1	22.6	1992	207	35.2	90.3	0.12	0.087	41.2
KEM 2	21.6	3027	333	46.2	94.9	0.30	0.130	34.1
KEM 3	28.0	1787	240	47.9	93.8	0.16	0.035	25.0
KEM 4	31.1	1147	195	61.7	124	0.084	0.045	38.7
KEM 5	34.2	1058	143	32.2	60.1	0.068	0.021	12.8

[1] Calculated from (Charcoal Mass)/(Dry Wood Mass) [2] Total non-methane hydrocarbons [3] Total suspended particulates

Table 1: Emissions data collected by Pennise et al. from earth mound kilns used for charcoal production in Kenya[6]

Societal Challenges for Sustainability

The labor-intensive nature of charcoal production, coupled with the imbalance of income discussed above, leads to high opportunity costs in the people associated with production and retail. Charcoal production often requires every member of the household to take an active part in the process in order to produce at even a level of subsistence. As a result, children in these situations often receive little or no education. This lack of education leads to limited options and availability of upward societal movement. Sustainability is not possible if players in the value chain are being trapped at the bottom of society. As Table 2 shows, producers possess the lowest average education level as well as the lowest percentage of ownership of such items as mobile phones and motorized transportation. Charcoal production occurs in rural areas and the product is then transported to urban areas so lack of motorized transportation serves to further reiterate the fact that these players are at a stark disadvantage to overcome the barriers to upward social movement on their own since they must be reliant upon transporters to get their product to the market place.

	Producer	Agent	Transporter	Trader	Retailer
Age (average years)	37	29	32	35	33
Education (average years of schooling	4.7	6.7	6.4	7.8	5.4
Bicycle (% ownership)	75	37	42	76	51
Mobile Phone (% ownership)	17	93	77	89	64
Radio (% ownership)	72	89	87	92	88
Motorcycle (% ownership)	2	22	35	23	9
Car (% ownership)	0	0	13	15	0
Truck/Boat (% ownership)	Not collected	0	32	3	0

Table 2: Demographic data collected by Shively et al. in a study focused on profits in the charcoal value chain in Uganda[7]

In addition to loss of education opportunity for producers, the inequitable distribution of profit across the value chain places both producers and retailers at distinct disadvantages to upward social mobility. This fact becomes more evident when examining the disparity of possessions detailed in Table 2. While possessions, or lack thereof, may be considered an economic issue, the particular distribution of possessions listed in Table 2 is reflective of each player's place in society. These items show a person's ability to communicate and travel. Without these two abilities, it is very difficult to grow in social standing.

Proposed Solutions to Sustainability Challenges

Economic Solutions for Sustainability

Solutions to the economic challenges facing sustainability in the charcoal sector of sub-Saharan are essential in helping to solve challenges faced in the other two realms of sustainability. The adverse effects of the governments' lost revenue resulting from tax and fee evasion in the charcoal industry permeate the other areas in the form of lessened enforcement capabilities. In order to remedy such a large problem, decisive action must be taken. The proposed manner in which to address the economic challenge of lost revenue due to evaded payment of taxes in the transport and warehouse portions of the charcoal value chain is for the governments to take over these duties. The taxes due on charcoal could then be added onto the sale price and the lost revenue would be reclaimed. The increased revenue would provide necessary funds to combat other problems such as illegal deforestation practices. This step would also serve to break up the concentration of power that currently exists in the middle of the charcoal value chain. The governments would not only have the power and capability to prevent tax evasion, they would also have the insight into the charcoal industry to be able to properly regulate it in a way that encourages sustainability.

This proposal could be brought to action through a "Charcoal Retailers Association" as described by Basu, Müller, and Soezer in their NAMA study for the United Nations Development Programme[4]. Under this proposal, governments would be in charge of purchasing the charcoal from the producers, transporting it to warehouses near urban areas, and distributing it to retailers. The charcoal retailers association would also provide other essential services to promote sustainability. They would be in charge of packaging and marketing sustainably produced charcoal in a way that would encourage the consumer to choose the more sustainable product. With this new association heavily involved in the charcoal sector, the charcoal retailers association could then provide supply and demand data on charcoal. This data would ensure that the price of charcoal was truly being market-driven.

The secondary challenge associated with this plan is, then, how to shape the marketplace such that sustainably produced charcoal is on equal footing with unsustainably produced charcoal. One way to do this would be to alter the tax structure associated with charcoal in a way that incentivizes producers to move toward sustainable practices. Presently, charcoal producers who play by the rules are put at a disadvantage because the taxes they pay raise the price of their charcoal. If taxes are being paid on all charcoal that is sold, a graduated tax system would work best to allow sustainably produced charcoal to be competitive. Under this plan, a producer who could show that the charcoal he is selling was produced using wood harvested from properly managed sources and that the production process was carried out in a sustainable manner would pay a substantially lower tax rate than someone who was producing unsustainable charcoal.[5] This lower tax rate would help to overcome the added costs associated with carrying out the charcoal production process sustainably. It is believed that if the cost of sustainable charcoal is comparable to charcoal that is produced in an unsustainable fashion; consumers will choose the charcoal that is best for their land. Over time, as more and more charcoal is produced in a sustainable manner, these tax rates could be adjusted to maintain the level of revenue needed by the government to oversee the rest of the charcoal industry.

Environmental Solutions for Sustainability

The illegal practices that are contributing to the large-scale deforestation of sub-Saharan Africa must be brought to an end in order for environmental sustainability to even be a consideration. By implementing the economic changes detailed above, the government would be in position to charge people with the task of regulating the native forests and protecting them from would-be poachers. However, simply preventing native forests from being clear-cut will not bring about sustainability. By themselves, such actions would only serve to greatly reduce the supply of wood for charcoal production and cause drastic increases in prices to the consumer. To insure that there is ample wood available to keep up with charcoal

demand, and that it is being produced sustainably, forest management programs must be put into place. Vos and Vis have detailed examples from different countries in Africa where forest management programs have been put into place with signs of success.[5] While each of these plans may not be suitable for every situation, together they provide guidelines and ideas of ways in which sustainable forest management practices can be put into place. In each case, if sufficient care is taken to ensure the sustainability of the wood being harvested from these forests, a forest certification program could serve to properly designate it as such.

Community forest management (Senegal)[2,9]

Under this arrangement, rural communities are granted ownership of forests near their village that has previously been controlled by the state. These communities are then charged with maintaining these forests sustainably according to prescribed criteria. Such a program can be beneficial on many levels. The forests receive the proper oversight without the government having to keep watch over rural areas. Instead, the people who already live out in these areas fulfill the task. Also, this plan increases the revenue of these communities as they are able to sell the wood or the right to harvest the wood.

Individual Reforestation (Madagascar)[9,10,11]

The individual reforestation plan takes marginal land and grants tenure rights to individuals in villages nearby. These individuals take the land that has fallen victim to deforestation and convert it into energy plantations. Once such land has been identified and registered, technical training is provided by non-governmental organizations (NGOs) so that the new caretakers are able to maintain these lands properly and efficiently. After the training is complete, the soil, which has been degraded by the illegal deforestation, is broken up using tractors so that new seedlings have a better chance of surviving. From there, the caretaker is responsible for everything else going forward. Productivity data is collected to make certain that the land is being properly utilized. This plan, like the community forest management plan, enables proper management of these lands without necessitating that government agencies being directly involved. Also, individual reforestation plans revitalize lands which have zero opportunity costs since they have already been destroyed by improper deforestation.

De-linking charcoal production and deforestation (Rwanda)[12,13]

In order to de-link charcoal production and deforestation, wood used for charcoal production must come almost exclusively from forest plantations. Rwanda was a prime candidate for this approach due to the fact that it was previously devastated by deforestation. It is also one of a limited number of countries in Africa that allow personal land ownership. Using this approach, coupled with reforestation practices,

Rwanda has begun increasing its forest cover. For this plan to work, farmers must convert their land to forest plantations. On these plantations, fast-growing trees such as eucalyptus are planted and harvested sustainably. Through this program, farmers have discovered that such wood plantations are profitable. Therefore, Rwanda continues to be able to meet its wood fuel needs while reclaiming its forests.

Concerning the problem of pollution that results from the production and use of charcoal, a move toward more efficient technologies is needed. Increased efficiency at the consumption level would require less charcoal be made in order to meet the energy needs of the people. This approach would require some sort of subsidy, perhaps funded with the increased revenue of properly collected taxes, to the consumer to offset the initial capital investment as many people who use charcoal as an energy source are low income. This reduction in demand paired with efficiency of conversion of wood to charcoal could greatly impact the number of trees needed to be cut in order to maintain a proper level of charcoal and subsequently reduce greenhouse gas emissions from pyrolysis.

Year	Casamance	Adam	Year	Casamance	Adam	Year	Casamance	Adam
2011	0%	0%	2016	100%	0%	2021	70%	30%
2012	0%	0%	2017	100%	0%	2022	50%	50%
2013	0%	0%	2018	95%	5%	2023	25%	75%
2014	100%	0%	2019	90%	10%	2024	10%	90%
2015	100%	0%	2020	80%	20%	2025	0%	100%

Table 3: Proposed progression of conversion of kilns in Uganda. Although the authors worked on a 20 year scale, only the first 15 years are shown here as there are no further changes in years 16-20 [4]

The current standard for charcoal production is a simple earth mound kiln. While these kilns can be moderately efficient if operated properly, moving toward more consistently efficient kilns is ideal if sustainability is going to be attained. In their NAMA study, Basu and Müller propose a twenty year progression where traditional earth mound kilns are replaced initially by casamance kilns and ultimately by Adam retort kilns.[4] Table 3 shows the proposed rate of conversion. Casamance is an improved type of earth kiln that incorporates air flow control through the use of a chimney. This type of kiln has been shown to produce charcoal at a higher average level of efficiency than traditional earth mounds, but the only reduction of greenhouse gas emissions comes from the reduced amount of wood needed to be pyrolized in order to produce the needed amount of charcoal. The Adam retort kiln not only further improves the efficiency of the charcoal production process, but also greatly reduces emissions. In the Adam retort kiln, the heat used to pyrolize the wood is generated in a separate fire box. The water in the wood is driven off first followed by the wood gasses. Once the wood gasses begin to be evolved, the flue gas is rerouted back through the fire chamber to be burnt prior to emission. This reduces harmful emissions such as methane by 75% compared to traditional earth mound kilns. The extra combustion in the fire chamber also serves to increase the amount of heat being produced for the pyrolysis.[9]

Societal Solutions for Sustainability

It seems that there exists no direct course of action by which to solve the societal problems of the charcoal trade in sub-Saharan Africa. However, many of the solutions described above for the other challenges facing sustainability in this industry would have positive effects on the societal aspects of charcoal in this region. Proper pricing, through market research conducted by the government through a charcoal retailers association, would increase the profits of producers and retailers. Increased profits would provide the means to acquire leisure and convenience items such as those listed in Table 2. These improvements would also increase these players ability for upward societal movement. Increased profits along with a tax structure that incentivizes sustainable production methods would encourage implementation of more efficient production technologies such as the improved kilns described above. These improved kilns would reduce the amount of manpower needed to carry out the process and would free up the children to receive more education than is currently possible for them.

Conclusions

The problems associated with the charcoal industry did not arise overnight. Neither, unfortunately, can they be solved in such a time frame. However, with careful implementation of the proposed solutions discussed in this case study, it is possible for movement toward sustainable charcoal production in sub-Saharan Africa. As is often the case, there exists a synergy between the different components of sustainable development. As the economic challenges are addressed by implementing a charcoal retailers association that ensures proper taxes are being paid, the government's ability to positively influence other areas will increase. The money needed to properly combat detrimental forest management practices will be available. In addition to cracking down on illegal deforestation, proper forest management practices will be instituted so that moving forward, charcoal will be produced using wood that is grown and harvested in a sustainable manner. Also, as a result of the charcoal retailers association, producers will be paid a proper amount for their product, and they will be encouraged to move toward more efficient methods of pyrolysis using improved kiln technology through the higher level of available capitol as well as lower tax rates on sustainably produced charcoal. As efficiency of production increases, the number of trees and levels of pollution will decrease. Through all of this, the level in society of the producers and retailers of charcoal will be improved through more expendable income and more time for education. Throughout this case study, it has been apparent that the barriers to sustainability being faced in this industry are great in scale and the proposed solutions described here are bold, but sustainability in the charcoal sector of sub-Saharan Africa is an attainable goal.

Instructor Objectives

1. Make students aware of fundamental concepts of sustainability and how the three areas (economic, environmental, and societal) can and must work together toward the "triple bottom line".
2. Discuss the pros and cons of governmental involvement in industries, such as charcoal in Africa, to help move them toward sustainability.
3. Present students with the reality that the developing world is not exempt to sustainability issues simply because they are not as industrialized as the first world.

Discussion Questions and Answers

1. **Which aspect of the economic issues discussed here presents the largest threat to a move toward sustainable production of charcoal going forward?**

   Answers here may vary depending on the students' perceptions of the problems. It is expected that either the tax evasion or concentration of power would constitute the largest threat to reforming the system. Perhaps these two issues work together in a way that makes their combined impact larger than the sum of their individual parts.

2. **Which challenge to sustainability presents the largest immediate threat to the people involved?**

   Again, there are no right or wrong answers to this question. The point is to get the students to examine the problems described in the case study with a focus on the immediate future and to develop supporting arguments to augment their choices. These answers could come from any of the three areas of sustainability.

3. **Are there other ways to incentivize sustainable production practices in the charcoal sector?**

   This question is designed to bring out the creative side in the students and allow them to develop their own grand plan to spur sustainable production of charcoal. There are a number of ways to

use incentives to encourage producers to adopt better methods. There is probably no answer that is without faults and merits, but getting the students to reasonably address the problem is the key.

4. **Is there a better way to regulate illegal transport of charcoal other than government assuming that role?**

   Depending on the ideologies that exist in the class, this may be a question that evokes great emotion. Government cannot solve every problem, but some problems are too large to be solved by the private sector alone. The debate of when and how to use governmental intervention is one that has never fully been resolved in this country. Temperance and reason are essential in order for this question to lead to profitable discussion.

5. **Societal barriers to sustainability are often linked to economics. What are some examples of exceptions to this statement?**

   So often, it is thought that more money solves all of society's problems. One example from this case study where money is not the vehicle for societal improvement is education. Education my very well lead to increased incomes in the lives of the children who receive it, but it is knowledge that opens social doors. This question, like others found here, is designed to encourage the students to look beyond just this study to the bigger picture of sustainable development and realize the complexity of it.

6. **What are some ways to reverse the damage that has already been done to the forests of these countries?**

   Reforestation is the simple answer here, but the methods may vary. The idea is that once sustainable forest management practices have halted deforestation and implementation of improved kiln technology has increased efficiency, there may be extra land which could be planted and allowed to return to an ecological equilibrium. Also, as these countries develop, more electrification will occur thereby reducing the demand for charcoal.

7. **Of the different approaches to implementing sustainable forest management practices, which do you think would be most effective?**

   This case study presents three approaches to forest management. Each method has advantages and disadvantages depending on the region or country being considered. A mixture of the plans will be the final results in Africa with people using the way that works best for them in their area. Also, encourage students to contribute ideas of their own.

8. **Introduction of improved cook stoves has been tried before. What are some ways to incentivize consumers to switch to these more efficient stoves?**

   This question is similar to the other question above about using incentives to persuade producers to adopt more efficient kilns. The difference here is that the consumer is not investing in a piece of equipment that they will use for profit. Remember that a large number of urban consumers of charcoal are quite poor with little to no spendable income. Without free giveaways by the government, it will be quite difficult to make this plan work.

References

1 Kambewa, P.; Mataya, B.; Sichinga, K.; Johnson, T. "Charcoal: the reality". **2007.** International Institute for Environment and Development (UK). London.

2 Peter, C.; Sander, K. "Environmental Crisis or Sustainable Development Opportunity? Transforming the charcoal sector in Tanzania". **2009.** The World Bank, A Policy Note.

3 Mugo, F. and Ong, C. 2006. Lessons of eastern Africa's unsustainable charcoal trade. ICRAF Working Paper no. 20. Nairobi, Kenya. World Agroforestry Centre.

4 Basu, A.; Müller, N., Soezer, A. "Nationally Appropriate Mitigation Action Study on Sustainable Charcoal in Uganda". **2010.** New York:UNDP.

5 Vos, J.; Vis, M. "Making Charcoal Production in Sub Saharan Africa Sustainable". **2010.** Netherlands Programmes Sustainable Biomass, Biomass Technology Group, BV.

6 "Global Environmental Outlook". United Nations Environmental Programme. Accessed 26 April 2013. http://www.unep.org/geo/geo3/english/178.htm

7 Pennise, D. M.; Smith, K. R.; Kithinji, J. P.; Rezende, M. E.; Raad, T. J.; Zhang, J.; Fan, C. "Emissions of Greenhouse Gases and Other Airborne Pollutants from Charcoal Making in Kenya and Brazil". *J. Geophys. Research.* **2001.** 106, 24,143-24,155.

8 Shively, G.; Jagger, P.; Sserunkuuma, D.; Arinaitwe, A.; Chibwana, C. "Profits and Margins Along Uganda's Charcoal Value Chain". *International Forestry Review.* **2010,** 12, 3, 270-283.

9 Sepp, S. "Wood Energy: Renewable, Profitable, and Modern. A collection of talking points for lobbyists". **2010.** GIZ Eschborn, Germany.

10 Sepp, S. "Promotion of Sustainable Charcoal Production Through Community Level Approaches-Experiences and Lessons Learned from Selected Sub-Saharan African Countries". **2008.** Eco Consulting Group, Oberaula, Germany.

11 "Le Reboisement Villageois Individuel". **2006.** Eco Consulting Group, Antananarivo, Madagascar: GTZ.

12 De Miranda, R. C.; Sepp, S.; Ceccon, E.; Mann, S.; Singh, B. "Sustainable Production of Commercial Woodfuel: Lessons and Guidance from Two Strategies". **2010.** ESMAP/WB, Washing DC, USA.

13 "Biomass Energy Strategy (BEST), Rwanda. Vol. 4-Proposed Strategy". **2009.** Marge.

14 Improved Charcoal Production System (ICPS). Accessed 30 April 2013. http://www.biocoal.org/3.html